When Super-Theories Collide: A Brief History of the Emergence/Reductionism Battles Between Particle Physics and Condensed Matter Theory

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OVERVIEW: In the last few decadesone of the most publicized controversies in fundamental physics has been the argument between condensed matter theory (CMT) physicists such as P.W. Anderson, Robert Laughlinand David Pineson the one hand,and particle physicists such as Steven Weinberg and Leonard Susskind on the other over whichtheoretical framework is in the best position to unify physics and lead it into the twenty first century. For reasons that will be made clear, CMT has been branded as the purveyor of emergence and particle physics considered the champion of reduction in this struggle. This battle still rages today in a volley of books and articles such as Laughlin's A Different Universe: Reinventing Physics from the Bottom Down (2005) and Susskind's The Cosmic Landscape: String Theory and the Illusion of Intelligent Design (2005). The key events in this fight will be detailed, from the publication of P.W Anderson's classic More is Different article (1972) to the protracted debates about whether or not to fund theSuperconducting Super Collider(SSC) andon up to the skirmishes of the present day. The historical significance of these machinations can only be fully appreciated when it is clear exactly what is at issue philosophically, methodologically and empirically between these two warring factions of fundamental physics. Thus by way of conceptual analysis, a taxonomy of various critical notions of emergence and reduction will be provided and the combatant's claims properly situated therein. Though as we shall see, this is no easy task as both sides equivocate madly in their use of the terms "emergence" and "reduction." In addition to raising profound ontological questions about the structure of the world such as the true nature of interlevel relations, epistemic questions about fundamental scientific explanation and intertheoretic relations, our history lesson suggests that theoretical physics (especially quantum gravity) may well be in a revolutionary Kuhnian state. We will find that there is fundamental disagreement over what is in fact fundamental and disagreement over how, if at all, the physical sciences and the world can be unified.

HISTORICAL BACKGROUND: The future of the supercolliderwas at stake: if other branches of physics follow logically from "fundamental" laws, then (manyargued) there were principled philosophical and practical reasons for funding the SSC. Thus, the alleged autonomy of condensed matter physics from the principles of particle physics had been debated from the physics communityall the way to the halls of Congress. Condensed matter physicists argued that the non-reductive autonomy of their field spoke against funding the SCC in a zero-sum game. Steven Weinberg's book dreams of a final theory was a pleafor "fundamentalism"and constructivist (asopposed to principle theories) metaphysics and a case for a multibillion-dollar colliderin Texas. Condensed matter physicists [such as Anderson in his famous 1972 article] asserted the importance of brokensymmetry in understanding real-world problems,suggesting an alternative approach to fundamental physics and implying that no single "grand" or "constructive" approach could capture the complexity or universality of nature. The physics community eventually fractured and the cohesive standard model narrative of the 1960s and 1970s began to dissolve. The narrative of fundamental symmetries of the universe as espoused by high-energy physicists in the 1960s and 1970s dissolved into a cacophony of competing narratives (strings, broken symmetry, condensed matter theory, etc.) that all made their own claims to being elegant and fundamental. By the end of the Cold War, particle physicists could not justifythe SCC (although some such as Weinberg tried) based on symmetry and fundamental entitiesas they had donein the 1960s, because the disunityof the physics community had undermined the plausibility of their storyas the gospel. "In the Demise of the SSC can be seen the confrontation of the simple, symmetric realm of

particle physics with the complexity and contingency of the real world. In the real world, on human scales where human problems count, symmetries are broken and condensed matter physics has direct relevance. The fragmentation of the physics community over superstrings, SDI, and the SSC in Cold War II mirrored this spontaneous breakdown of order; no longer could any one story be told about HEP, no longer wasthere space and time for any grand narrative of physics"(Hallam Stevens, 2003, HSPS, p. 153). Finally, one key battle in this war was over recruitment. Regardless of the money moving into physics through SDI and the SSC, recruitment into HEP was low through the early 1980s. However, by contrast Condensed-matter physics and molecular biology were heavily funded.In the late 1980s The Scientist wasspeaking about a "civil war" within the physics community. Some condensed matter physicists contemplated seceding from the APSto form their own organization.

CONCEPTUAL FOUNDATIONS OF THE HISTORICAL DEBATE: Of most interest to us were the claims of P.W. Anderson and other CMT folk that HEP is in no significant way more intellectually profound or fundamental than more (relatively speaking) "applied" branches of physics such as CMT. Steven Weinberg made many practical arguments for SSC but of special interest to us is his claim that "particle physics [QM, QFT, GR and cosmology] is in some sense more fundamental than other areas of physics" (2001, p. 12).One interesting thing about the historical battle over the SSC is at bottom it was a philosophical disputeabout what is fundamental and what is emergent and indeed, a battle over how to define these very terms. Unsurprisingly, both sides were guilty of equivocation and vaguenessall around, especially as pertaining to ontological versus methodological disputes. Part of the goal of this paper is to disambiguate this mess and disentangle the deeper philosophical issues.This seems like an especially useful and timely enterprise in that there are lessons here for current debates over emergence and reduction.